Claims

1. A multistage axial flow pumping device comprising:

a housing,

a longitudinal chamber within the housing to convey a working fluid from an inlet to an outlet, said chamber including at least two rotor stages that each include a rotor section, said chamber further including a stator section between respective rotor sections,

said rotor section including a multi-bladed drive wheel positioned downstream of said inlet and operative to rotate around an axis to thereby to pump working fluid from the inlet to the outlet through a high pressure section defined within said chamber, and

said stator section being positioned downstream of a rotor section and including plural stator vanes substantially fixed relative to said housing and geometrically arranged to define a flow path having a cross-sectional area between vanes that increases from an entry point to an exit point of the stator section.

2. The device of claim 1, wherein said stator vanes are variable in pitch to adjust the angle of attack of the working fluid upon entry into a following rotor section.

3. The device according to claim 1, wherein said outlet comprises a convergent annular chamber at a discharge nozzle whereby to increase velocity of liquid discharged from said outlet.

4. The device of claim 3, wherein said convergent annular chamber includes a variable throat area positioned immediately upstream of said outlet to vary the velocity of the liquid discharged from said outlet.

5. The device of claim 4, further including an actuator to vary the axial position of a nozzle plug whereby to vary effective area of said outlet.

6. The device of claim 4, further including balancing pistons operated by pressure differentials obtained by sensing discharge nozzle jet velocity and vessel velocity respectively to obtain a desire optimum discharge velocity relative to vehicle velocity.

7. The device of claim 6, further including a nozzle plug position override effective to reposition said nozzle plug by overriding automatic positioning of said balancing pistons with hydraulic pressure.

8. The device of claim 1, further including at least one variable inlet guide vane positioned downstream of said inlet and operative to adjust the whirl angle of fluid entering said inlet.

9. The device of claim 1, further comprising a fixed set of inlet guide vanes positioned downstream of said inlet to adjust inlet whirl angle of liquid entering said inlet.

10. The device of claim 9, further comprising an inlet diffuser serving as an inlet duct positioned upstream of said inlet guide vanes.

11. The axial flow pumping device of claim 1, further comprising a larger diameter booster section preceding the high pressure section and operative to increase fluid pressure at said inlet.

12. The axial flow pumping device of claim 11, wherein said booster section comprises multiple rotor stages, said booster section further including a stator section between respective rotor sections.

13. The axial flow pumping device of claim 11, wherein said booster section includes variable discharge nozzles and an actuator to control the discharge nozzles to maintain a given pressure at the inlet of the high pressure section.

14. The axial flow pumping device of claim 11, wherein said booster section further includes variable pitch stator vanes.

15. The axial flow pumping device of claim 11, further comprising a common drive shaft for said pumping device and said booster section.

16. The axial flow pumping device of claim 11, wherein said booster section includes a set of inlet guide vanes to control the whirl angle of incoming fluid.

17. The axial flow pumping device of claim 1, wherein said longitudinal chamber has a cross-sectional area that initially decreases in a downstream direction and that subsequently increases upstream of said outlet to form an expansion region prior to discharge of the working fluid whereby to convert ram pressure of higher speed working fluid to static

pressure in lower speed working fluid in order to reduce internal friction within said longitudinal chamber and to improve propulsive efficiency of said pumping device.

18. The axial flow pumping device of claim 17, wherein said longitudinal chamber is annular.

19. The axial flow pumping device of claim 18, wherein rotor and stator vanes of successive stages in the chamber have decreasing heights in the downstream direction and rotor blade drive wheels have corresponding increasing diameters in the downstream direction

20. The axial flow pumping device of claim 18, wherein rotor and stator vanes of successive stages in the chamber have decreasing heights and the housing diameter decreases in the downstream direction to attain a decreasing effective area of the annular chamber in the downstream direction.

21. The axial flow pumping device of claim 18, wherein rotor and stator vanes of successive stages in the chamber have increasing heights in the downstream direction and rotor blade drive wheels have corresponding decreasing diameters in the downstream direction.

22. The axial flow pumping device of claim 18, wherein rotor and stator vanes of successive stages in the chamber have increasing heights and the housing diameter increases in the downstream direction to attain an increasing effective area of the annular chamber in the downstream direction.

23. A method of conveying a working fluid through an axial flow pumping device comprising:

defining a flow path in the axial flow pumping device to convey the working fluid from an inlet to an outlet,

providing multiple stages within said flow path that each include a rotor section,

providing at least one stator section between at least two rotor sections,

driving working fluid through said flow path by rotating the rotor section, and

lowering the speed of working fluid in said path by providing increased flow path areas between vanes of the stator section as the working fluid travels in the downstream direction.

24. The method of claim 23 wherein said inlet includes variable inlet guide vanes having controllable pitch and said method further including controlling the whirl angle at said inlet by altering the pitch of said inlet guide vanes.

25. The method of claim 23 wherein said outlet includes an exit guide vane stage operative to straighten flow of said working fluid and to increase static pressure prior to discharge.

26. The method of claim 23, further including boosting pressure of said working fluid prior to conveying the working fluid from the inlet to the outlet.

27. The method of claim 23, further comprising oppositely altering ram and static pressure of the working fluid by varying the cross-sectional area of the flow path in the downstream direction whereby to reduce internal friction and improve propulsive efficiency.

28. A method of controlling discharge velocity of water discharged from an axial flow pumping device relative to water speed a vessel, said method comprising:

detecting discharge velocity of water discharged from the axial flow device,

detecting water speed of the vessel,

providing a discharge nozzle in said axial flow device having a variable area throat, and

utilizing said discharge velocity and boat velocity to control the area of said throat according to a desired set point based on the discharge velocity of the water and the speed of the vessel.

29. The method of claim 28, further comprising providing an actuator that drives the discharge nozzle, said detecting steps includes detecting respective pressures associated with said discharge velocity and water speed of the vessel, and said utilizing step includes using the respective pressures to drive said actuator to an equilibrium position that defines a desired optimum throat area of the discharge nozzle.

30. A dual flow axial flow liquid pumping device comprising:

a low pressure section that conveys liquid along a downstream path in a chamber having a first cross-sectional area,

a high pressure section in communication with the low pressure section that conveys said liquid along a downstream path in a chamber having a second cross-sectional area that is smaller than said first cross-sectional area, and

said first and second sections each having at least one rotor-stator stage mounted on respective shafts that drive the respective stages to stepwise pressurize the liquid in the respective sections.

31. The dual flow axial flow liquid pumping device of claim 30, wherein at least one of said high and low pressure sections includes a set of stationary vanes operative to increase static pressure between said at least one rotor-stator stage of a section by converting ram pressure of the liquid to static pressure.

32. The dual flow axial flow liquid pumping device of claim 31, wherein said low pressure and high pressure sections have concentric annular chambers in communication with each other and said low pressure section includes control nozzles that control discharge of liquid around the annular chamber of said high pressure section.

33. The dual flow axial flow liquid pumping device of claim 32, wherein said respective shafts are common.

34. The dual flow axial flow liquid pumping device of claim 32, wherein said respective shaft are geared together to provide different rotational speeds of the respective shafts.

35. A dual flow pumping method that pumps water during water jet propulsion, said method comprising:

pressurizing the water at a first lower pressure,

conveying the water along a first downstream path having a first cross-sectional area,

utilizing the first lower pressure of the water to establish a higher pressure in said water along a second downstream path having second cross-sectional area that is smaller than said first cross-sectional area,

providing at least one rotor-stator stage in each of said first and second downstream paths in order to stepwise pressurize the water in each path, and

powering said rotor stator stages in each path to propel a vessel by water jet propulsion.

36. An water jet propulsion device comprising:

a propulsion pump; and

a diffuser preceding said propulsion pump, said diffuser including an inlet, a larger outlet in communication with said propulsion pump, multiple sections between said inlet and outlet that have increasing cross-sectional area in the downstream direction, and multiple groups of deflector vanes between said sections that re-direct and convert ram pressure of the liquid to static pressure between respective sections.

37. The propulsion device of claim 36, wherein said deflector vanes are positioned between respective sections to re-direct said liquid approximately 30° from a nominal flow direction of a preceding section.